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From the Combat Medic to the Forward Surgical Team: The Madigan Model for Improving Trauma Readiness of Brigade Combat Teams Fighting the Global War on Terror^{1,2}

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Background. Medics assigned to combat units have a notable paucity of trauma experience. Our goal was to provide intense trauma refresher training for the conventional combat medic to better prepare them for combat casualty care in the War on Terror.

Materials and methods. Our Tactical Combat Casualty Care Course (TC3) consisted of the following five phases: (1) One and one-half-day didactic session; (2) Half-day simulation portion with interactive human surgical simulators for anatomical correlation of procedures and team building; (3) Half-day of case presentations and triage scenarios from Iraq/Afghanistan and associated skills stations; (4) Half-day live tissue lab where procedures were performed on live anesthetized animals in a controlled environment; and (5) One-day field phase where live anesthetized animals and surgical simulators were combined in a real-time, field-training event to simulate realistic combat injuries, evacuation problems, and mass casualty scenarios. Data collection consisted of surveys, pre- and post-tests, and after-action comments.

Results. A total of 1317 personnel participated in TC3 from October 2003 through May 2005. Over the overlapping study period from December 2004 to April 2005, 327 soldiers participated in the formal five-phase course. Three hundred four (94%) students were combat medics who were preparing for combat operations in Iraq or Afghanistan. Of those completing the train-

ing, 97% indicated their confidence and ability to treat combat casualties were markedly improved. Moreover, of those 140 medics who took the course and deployed to Iraq for 1 year, 99% indicated that the principles taught in the TC3 course helped with battlefield management of injured casualties during their deployment.

Conclusion. The hybrid training model is an effective method for training medical personnel to deal with modern battle injuries. This course increases the knowledge and confidence of combat medics deploying and fighting the Global War on Terrorism. © 2007

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Key Words: trauma simulators; war surgery; combat medic; first responder.

INTRODUCTION

The terrorist attacks of September 11, 2001 thrust the United States military into a war that has produced combat casualties unseen since the Vietnam era. While training for war is an everyday goal of our armed forces, the reality is that support of peacetime priorities can compete with this mission [1]. Subsequent transition into combat operations is associated with a "learning curve" that must be overcome [2]. This is especially true for military personnel whose primary peacetime role does not include war-fighting, such as medics. Combat medics are first-responders who triage, treat, and evacuate the wounded from the front lines of battles with limited resources and in austere environments.

An Army medic's training consists of 16 weeks of Advanced Individual Training (AIT) at Fort Sam Houston, Texas. There, the soldier learns basic medical skills and graduates with a civilian equivalent of an

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² The views expressed in this article are those of the authors and do not reflect the official policy of the Department of the Army, the Department of Defense or the U.S. Government.

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Emergency Medical Technician-Basic (EMT-B) designation. Without further specific trauma training, most go on to join a battalion medical platoon composed of 20 to 30 other medics to augment and serve the battalion's 650–690 combat soldiers. Thus, each medic is responsible for 20–30 lives during battle. Other assignments for medics include hospitals or non-patient-oriented administrative duties. Regardless of the assignment, however, outside of the combat theater, most medics do not take care of critically injured patients, nor are they consistently exposed to trauma. Realizing that our medics had limited exposure to real-time trauma management before engaging in combat casualty care, we sought to design and implement a refresher hybrid training model to provide specific trauma training for the conventional medic deploying in support of the Global War on Terrorism. The goal was to help bridge the gap between the peacetime medic and the experienced combat medics returning from war today. The ideal outcome was to save as many lives on the battlefield as possible; a more quantifiable end point was to subjectively evaluate whether this model helped students take care of battlefield casualties, improve their confidence in combat casualty care, and increase their fund of knowledge and procedural skill set.

MATERIALS AND METHODS

Course Design

The original Tactical Combat Casualty Care (TC3) concept was developed for the Special Forces community by Butler and Hagmann in the 1990s [3]. This course offered training in applicable topics that were emphasized by case-based scenarios from real-world, special operations casualties. Additionally, it emphasized procedural skills labs, mostly on anesthetized animals. We sought to expand the participation of this course to conventional combat medics who are currently the most engaged medical personnel in the war.

The Madigan Model of the TC3 course is a marked variation of the original course developed by the Army Medical Department Center and School, San Antonio, Texas (permission granted to use a similar name). Our hybrid Tactical Combat Casualty Care Course consists of the following five phases: (1) A one and one-half-day didactic session; (2) half-day simulation portion with interactive human surgical simulators for anatomical correlation of procedures and team building;

TABLE 1

Core Lecture Program

Wound injury statistics/mechanisms of injury
Patient assessment, tactical stages of care
Airway management
Shock
Hemorrhage control
Fluid therapy
Extremity trauma
Abdominal/thoracic trauma
Analgesia, anesthesia, and antibiotics
Burns
CNS/head/spinal injury
Medicine in nuclear, biological, chemical (NBC) environment

TABLE 2

Medical Simulation Mannequin Procedures

Trauma assessment
Endotracheal intubation and airway management
Surgical airway
Venous access (to include interosseous line placement)
Tube thoracostomy
Tourniquet application
Team triage and resuscitation scenarios

(3) half-day of case presentations and triage scenarios from Iraq/Afghanistan with associated skill stations; (4) half-day live tissue lab where procedures were performed on anesthetized animals in a controlled environment; and (5) one-day field phase where live anesthetized animals, moulage casualties, and surgical simulators were combined in a real-time, field-training event to simulate realistic combat injuries, evacuation problems, and mass casualty scenarios. Volunteer instructors participated in all five phases of the course and included physician assistants, veteran medics, and staff surgeons, all with combat experience.

The didactic lectures (Table 1) incorporated trauma concepts likely to be important to both civilian and military first responders, with an emphasis on unique aspects of the austere and hostile wartime environment. Unlike civilian teaching, however, these lectures also integrate the three phases of battlefield prehospital care: care under fire, tactical field care, and casualty evacuation care [4]. Battlefield care is sometimes different under combat conditions than in a stateside emergency room. For instance, while under fire, the best way to prevent further injuries is to first return fire on the enemy to neutralize or suppress him so that you may then proceed to care for casualties safely and obtain the military objective. While under fire, simple things are addressed such as placing a tourniquet to stop exanguinating extremity hemorrhage. In phase two, procedural tasks, treatment team exercises, and scenario training were performed on medical simulation mannequins, or SimMan (Laerdal Inc., Wappingers Falls, NY) (Table 2). Procedural proficiency, subjectively determined by each instructor, was required before proceeding to the live tissue portion of the lab. Phase three allowed for small group discussions of case-based scenarios from casualties of recent combat actions. The fourth phase of the curriculum exposed students to live tissue familiarity by performing procedures on goats, taught by veteran medics under the direct supervision of combat-experienced surgeons (Table 3). Student-to-animal and student-to-instructor ratios were 4:1. Maneuvers most commonly performed in theater by medics, such as external/extremity hemorrhage control with tourniquets and/or hemostatic dressing application, splinting, and airway protection were emphasized.

The culminating event was the field training exercise (FTX), consisting of day and nighttime missions. In this outdoor event, trainers sought to mimic wartime conditions and present likely cases and

TABLE 3

Live Tissue Procedures

Venous access
Fracture/amputation management (splint and dressing application)
Tourniquet application
Direct pressure hemostasis
Hemostatic dressing application (Chitosin and QuickClot)
Management of evisceration and mesenteric bleeding
Tube thoracostomy
Surgical airway
Physiologic monitoring



FIG. 1. In the field phase of the course, trauma simulators, and live animal models with categorized injuries are combined in real time scenarios. Medics are expected to secure the scene, triage the wounded, treat life threatening injuries, and then evacuate the casualty to the next echelon or level of care, usually the battalion/brigade aid station or the forward surgical team if urgent lifesaving surgery is needed.

mass casualty situations to test students in their ability to perform learned tasks. The sequence of events was customized to each individual unit, taking into consideration their mission, available equipment, capabilities, and anticipated role while deployed. For example, a mechanized infantry unit would incorporate their armored vehicles into a scenario to seek and treat downed friendly aviators in enemy territory. Medics participating in the course treated the wounded soldier (goat or mannequin) and evacuated the "casualties" to an awaiting forward surgical team. Rotary winged aircraft were incorporated into the evacuation plan and execution. During the FTX, anesthetized goats with various injury patterns, medical simulation mannequins, and moulage "casualties" represented therapeutic dilemmas for the students to identify, assess, treat, and evacuate (Figs. 1 and 2). Night missions tested the students' abilities to perform the same tasks but with the additional stressors of reliance on night optical devices and other nighttime tactical principles [5].

Participant Groups and Subjects

From October 2003 until May 2005, soldiers deploying to combat operations in Iraq or Afghanistan participated in the TC3 course at Fort Lewis, Washington. The course was open to all units; participating units had to be mission capable and have deployment orders within 6 months from time of the course, and medical personnel from the unit had to attend as a team. All personnel were briefed on the ethical treatment of animals at the beginning of the course and were given the opportunity to forego the animal portion of the course.

Animal Handling

Veterinary personnel ensured each goat (*Capra hircus*) was properly anesthetized throughout the exercise in accordance with an approved protocol by our Institutional Animal Care and Use Committee. Ratio of veterinary technicians to animal for both controlled procedures lab and the FTX was 1:2. General anesthesia was used for pain control and all animals were euthanized during general anesthesia at the end of the lab. Induction and maintenance of anesthesia during the procedures lab was performed using atropine, ketamine/xylazine, and isoflurane after endotracheal intubation. For

the field phase, a ketamine-based regimen was used and re-dosed at 30- to 45-min intervals or at the discretion of the on-site veterinarian.

An adjustment was made to the protocol at the midpoint in the study period that allowed medics to use the veterinary-placed IV for fluid administration in the field phase due to some goats not surviving to the end point in the exercise from hypovolemic shock and hypothermia. The goat model is not ideal for venous access practice and much time was taken to obtain such access with the result of personnel not having the opportunity to treat other injuries.

Data Collection

A one-page postcourse questionnaire was administered (Table 4) upon completion of the training. A similar post-deployment questionnaire was given as soon as units returned from their deployment. Approximately halfway through the study period, pre- and post-course tests were administered, graded, and immediate results given to each participant. Additionally, immediate group critiques were conducted after the field phase of each course.

Statistical Analysis

The Wilcoxon signed ranks test was used to evaluate significance between question answers comparing precourse *versus* postcourse confidence in the participants ability to care for combat casualties. Other continuous data were analyzed using the Student's *t*-test.

RESULTS

Nine hundred ninety medical personnel completed earlier, less-rigid versions of TC3 from October 2003 through November 2004. During our study period from December 2004 to May 2005, 327 soldiers participated in the full, 4-day course. Three hundred eight (94%) postcourse, pre-deployment questionnaires were completed by combat medics. The remaining attendees were



FIG. 2. An appropriately placed CAT-I tourniquet applied during live tissue phase of training. All medics are expected to perform this task on all casualties before evacuation. Animals involved in this study were maintained in accordance with the 'Guide for the Care and Use of Laboratory Animals' published by the National Research Council/Institute of Laboratory Animal Research and our local IACUC/IRB approved protocol. (Color version of figure is available online.)

TABLE 4
Questions Asked on the Questionnaire and Corresponding Average Likert Score

Survey question	Likert score average (1 = strongly agree, 5 = strongly disagree)
1. The lecture portion of the course contained topics not covered in previous Army training.	1.79
2. The SimMan (practice surgical simulator/mannequin) portion of the course taught me procedures not taught in previous Army training.	2.55
3. The animal lab (goat) portion of the course taught me procedures not covered in previous Army training.	1.38
4. The SimMan (practice mannequin) and the anesthetized goats used in the FTX (field portion) added to my unit's medical readiness.	1.48
5. Before I took the course, I was prepared to go into battle and take care of casualties.	2.79*
6. Now that I have taken the course, I am prepared to go into battle and care for casualties.	1.63*
7. I would take this course again if offered.	1.24

* Significant difference between related responses ($P = 0.01$).

physician assistants, nurses, or infantrymen. Thirty-six (11%) of the respondents were from medical units, while the remainder comprised medics from mechanized infantry units. By unit assignments, 196 (60%) were combat medics attached to combat units. One hundred seven (32%) were assigned to a forward area of care. Twenty-four attendees (7%) were assigned to either ground or air ambulance units.

Postcourse, Pre-Deployment Confidence

Improved trauma readiness and confidence were measured by questions five and six of the questionnaire that specifically addressed whether the student felt an improvement in his/her confidence in taking care of injured soldiers on the battlefield. Of the pre-deployment responses, 143 (44%) of respondents either strongly agreed or agreed that they were prepared to go into battle and care for casualties prior to taking the course (Fig. 3). Eighty (24%) students either disagreed or strongly disagreed that they were ready. In contrast, 297 (91%) attendees either strongly agreed or agreed that the course improved their confidence in taking care of injured soldiers on the battlefield. Twenty-nine (9%) respondents were unsure; 2 (1%) respondents dis-

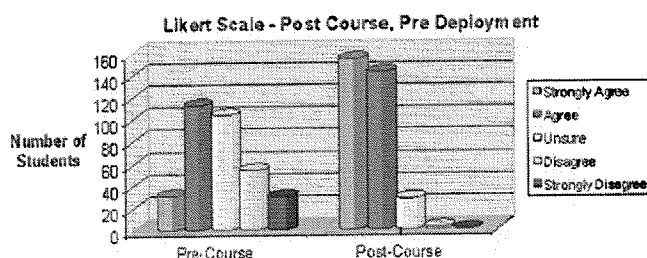


FIG. 3. Combat medic perceived preparedness and confidence both before the TC3 course and afterward. Medics were significantly more confident in their ability to take care of combat casualties after completing the course, $P < 0.01$.

agreed, and no one strongly disagreed that this course was helpful. The difference in participant confidence before and after the course was significant ($P < 0.01$). Furthermore, 96.6% of the participants stated that they would take the course again if offered. Of the four personnel who would not take it again, 2 (0.5%) cited discomfort in performing procedures on lab animals.

Simulator Training versus Live Animals

In postcourse critiques, an overwhelming majority of participants expressed satisfaction with the animal procedures lab. When asked whether previous army training had covered the procedures and skills taught in the course, the live animal lab scored significantly higher than the simulator portion of the course, average Likert scores of 1.48 versus 2.55, $P < 0.01$ (1 = strongly agree that the training was not covered before, 5 = strongly disagree).

Knowledge Testing

As we sought improvement on quantifiable metrics in student evaluations, the last 164 participants took written examinations. Pre- and postcourse tests were used to measure improvements in knowledge. The mean pretest score was 73% and the mean posttest score was 91%, indicating a significant increase in scores, $P < 0.01$ (Fig. 4). Only 3 participants scored lower on the posttest as compared to their pretest score and 10 showed no change.

Postcourse, Post-Deployment Assessment

After a yearlong deployment to Iraq, 140 students participated in the postcourse, postdeployment survey. When questioned regarding precourse battlefield casualty care, 84 (60%) students strongly agreed or agreed that they were prepared for combat (Fig. 5). Sixteen (11%) students disagreed or strongly disagreed about

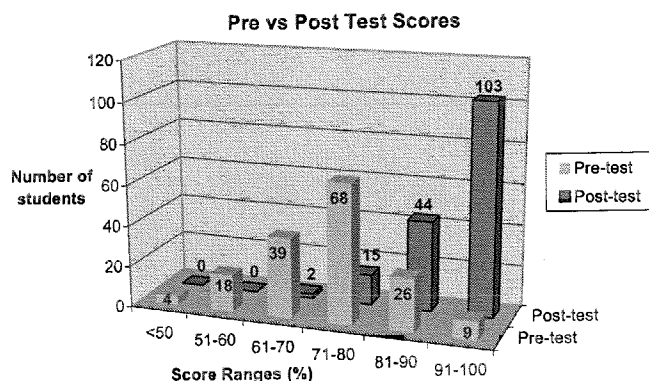


FIG. 4. Distribution of student scores for the pretest and posttest. Average pretest score = 73%. Average posttest score = 91%.

feeling adequately prepared. More importantly, 138 (99%) indicated that the principles taught in the TC3 course helped with battlefield management of injured casualties during their deployment.

DISCUSSION

Data from Vietnam and subsequent conflicts show that most of those killed in action die as a result of injury to the central nervous system or from exsanguination [6]. Other leading causes were tension pneumothorax and airway obstruction. Thus, a small number of key basic skills are important in effectively intervening in life-threatening situations. The ability of military first responders to acquire these skills and sustain their expertise is increasingly limited by the lack of exposure to trauma outside of the combat experience. Subsequently, some find themselves having to perform such maneuvers often for the first time unsupervised, under emergency and adverse conditions on injured fellow soldiers or civilians whose lives are at risk. Adapted from the training program of Special Forces medics who are often required to be self-reliant in austere environments, we trained our conventional combat medics in a similar fashion by combining formal lectures and medical simulation with hands-on live tissue procedures. The goal of this study, to provide an intense, trauma refresher course relevant to combat casualty care, was met.

Loosely modeled after proven successful methods of Advanced Trauma Life Support (ATLS), TC3 also employs didactic lectures, case-based scenarios, small groups, in addition to skills stations that encourage the cognitive process and performance of psychomotor skills [7]. These innovative aspects of learning trauma care are far more effective than the traditional methods such as a series of didactic lectures. We have fully embraced these principles [8]. Of course, as previously illustrated, we have modified key aspects with our

target audience in mind. For instance, while ATLS incorporates and encourages "moulage" to simulate realistic environments, our course not only used "moulage" and goat casualties, but also different aspects of battlefield triage including artillery simulators, "enemy" combatants, basic infantry tactics, and procedures for medical aeroc evacuation [9]. Furthermore, in much the same way that ATLS has continued to evolve since its initial inception in 1978 [10], TC3 has also undergone a series of improvements, based on user feedback and results of casualty treatment from the war.

The demand for medical simulation using models and mannequins has expanded exponentially within the past decade. In a meta-analysis for the Department of Defense, Champion and Higgins [11] explored whether incorporating medical simulation for combat trauma training was beneficial. Their study ultimately recommended hybrid technologic applications that include virtual environments, mannequins, and real world medical training for the optimal solution. The military initially demonstrated interest in this field with the use of computer enhanced mannequins in 1995. The U.S. Army Telemedicine and Advanced Technology Research Center (TATRC) seeks to further improve combat readiness of medical personnel with simulation models [12]. An effort is being made to gather lessons from simulation training in other domains and apply them toward the design and development of an efficacious simulation training program in medicine.

Even outside of the military, virtual medical simulators have percolated into physician training programs. Benefits in performance, assessment, training, decreased rate of error, and increased hand-eye coordination have been demonstrated in a myriad of medical skills including virtual colonic endoscopy [13], acute care management skills [14], laparoscopic cholecystec-

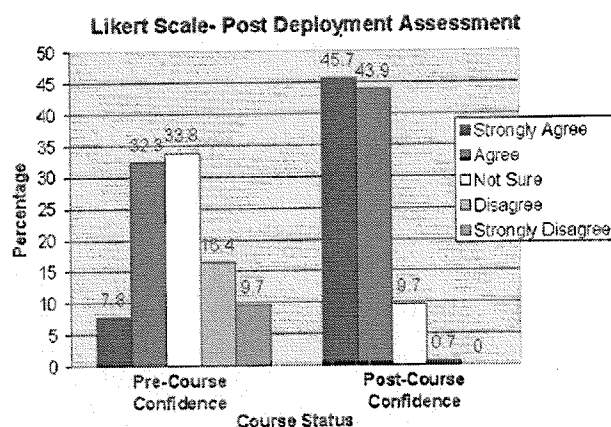


FIG. 5. After returning from deployment, medics were asked what their perception was of whether they were prepared to take care of the combat casualties they treated from the perspective of before and after they had completed the TC3 course. Again, there was a significant improvement of their perceived abilities as a result of having taken the TC3 course, $P < 0.01$.

tomy [15], ureteroscopy [16–18], bronchoscopy [19], and endotracheal intubations [20]. Specifically, in light of the changing landscape of surgical education due to the 80-h work restriction, hybrid simulation training models such as ours may enhance the efficiency of trauma training for surgery residents. For instance, proctors cannot only create specific trauma scenarios, they can assess competency and proficiency of surgical residents performing an array of basic to complex surgical maneuvers that are often required for trauma surgery. Both time to complete the task and an accuracy/completeness score can be given. Furthermore, educators can adhere to work week limitations while still providing focused critical training to young surgeons.

For TC3, the best quantifiable determination of success was based on two questions designed to assess a participant's perceived confidence in treating battlefield casualties prior to and following our training model. Most convincing was that 97% of the questioned medics, after having spent 12 months in Iraq, believed the Tactical Combat Casualty Care Course aided in the management of battlefield casualties. A teaching point not quantifiable is the hesitance and the "frozen" in place stance of many young combat medics that was repeatedly observed by the instructors in our controlled procedures lab when for the first time they were exposed to seemingly uncontrollable hemorrhage from a proximal femoral artery injury in our goat model and had to be "coaxed" to act. It was gratifying to observe their subsequent euphoria in being led through the successful implementation of the algorithm of direct pressure, pressure point, tourniquet, and application of a hemostatic dressing in which the saving of a "life" resulted. It is difficult to simulate this in an inanimate model [11].

The limitations of this study are acknowledged by the lack of outcomes data from the battlefield with relation to TC3 trained medical personnel. Another confounding factor is that many of those treated in Iraq include civilians and foreign coalition troops, with neither population following up in American facilities. To provide objective data, we recently initiated pre- and postcourse written examinations for the medics and found that the scores have improved from average of 73 to 91%. Another limitation is the apparent disparity is between those participants who attended the course *versus* those captured with a postcourse survey. During the initial phases of this course, comments on the course were handled internally and done in informal sessions immediately following the course. This is different than the questionnaire currently being administered as a way of standardizing postcourse analysis.

Besides improving our data collection on the efficacy of our teaching methods, we continually tailor

our curriculum to the most relevant topics. The clinical applications of this model are endless and relevance to civilian practice is limited only by imagination and funding.

CONCLUSION

Hybrid combinations of teaching techniques, each emphasizing different aspects of learned concepts, are thought to provide the most effective training instruments. Our hybrid training model proposed and tested here has shown to (1) expose army front line combat medics to casualty treatment algorithms, techniques, and procedures they had not seen in prior training; (2) improve their knowledge base; and (3) improve confidence in performing their most important mission—caring for wounded soldiers and civilians on the battlefield.

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